FORM PTO-1390 (Modified) (REV 11-98) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER: **204207US2PCT**

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR): 09/786352

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/JP00/04673	**12 July 2000**	**15 July 1999**

TITLE OF INVENTION

METHOD, APPARATUS, COMPUTER PROGRAM, COMPUTER SYSTEM AND COMPUTER-READABLE STORAGE FOR REPRESENTING AND SEARCHING FOR AN OBJECT IN AN IMAGE

APPLICANT(S) FOR DO/EO/US

Miroslaw Z. BOBER

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☐ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
   a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☒ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☒ A copy of the International Search Report (PCT/ISA/210).
8. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
   a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☒ have not been made and will not be made.
9. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
10. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
11. ☐ A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).

Items 13 to 20 below concern document(s) or information included:

13. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
14. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☒ A **FIRST** preliminary amendment.
16. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
17. ☐ A substitute specification.
18. ☐ A change of power of attorney and/or address letter.
19. ☐ Certificate of Mailing by Express Mail
20. ☒ Other items or information:

Request for Consideration of Documents Cited in International Search Report
Notice of Priority
PCT/IB/308
Drawings (2 Sheets)
Form PTO-1595(2)
(2) Assignments

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR)	INTERNATIONAL APPLICATION NO.	ATTORNEY'S DOCKET NUMBER
09/786352	PCT/JP00/04673	204207US2PCT

21. The following fees are submitted:.

BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)) :

		CALCULATIONS PTO USE ONLY
☐	Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2) paid to USPTO and International Search Report not prepared by the EPO or JPO	**$1,000.00**
☒	International preliminary examination fee (37 CFR 1.482) not paid to USPTO but Internation Search Report prepared by the EPO or JPO	**$860.00**
☐	International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO	**$710.00**
☐	International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provisions of PCT Article 33(1)-(4)	**$690.00**
☐	International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1)-(4)	**$100.00**

ENTER APPROPRIATE BASIC FEE AMOUNT =	**$860.00**	
Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (e)).	**$0.00**	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	23 - 20 =	3	x $18.00	**$54.00**	
Independent claims	5 - 3 =	2	x $80.00	**$160.00**	
Multiple Dependent Claims **(check if applicable)**.			☐	**$0.00**	
TOTAL OF ABOVE CALCULATIONS =				**$1,074.00**	
Reduction of 1/2 for filing by small entity, if applicable. Verified Small Entity Statement must also be filed (Note 37 CFR 1.9, 1.27, 1.28) **(check if applicable)**.			☐	**$0.00**	
SUBTOTAL =				**$1,074.00**	
Processing fee of **$130.00** for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (f)).			+	**$0.00**	
TOTAL NATIONAL FEE =				**$1,074.00**	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) **(check if applicable).**			☒	**$80.00**	
TOTAL FEES ENCLOSED =				**$1,154.00**	
				Amount to be: refunded	$
				charged	$

☒ A check in the amount of **$1,154.00** to cover the above fees is enclosed.

☐ Please charge my Deposit Account No. in the amount of to cover the above fees.
A duplicate copy of this sheet is enclosed.

☒ The Commissioner is hereby authorized to charge any fees which may be required, or credit any overpayment to Deposit Account No. **15-0030** A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

22850

Surinder Sachar
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Surinder Sachar
SIGNATURE

Marvin J. Spivak
NAME

24,913
REGISTRATION NUMBER

March 13 2001
DATE

DOCKET NO. 204207US2PCT

IN RE APPLICATION OF: Miroslaw Z. BOBER

SERIAL NO.: New U.S. PCT Application (Based on PCT/JP00/04673)

FILED: HEREWITH

FOR: METHOD, APPARATUS, COMPUTER PROGRAM, COMPUTER SYSTEM AND COMPUTER-READABLE STORAGE FOR REPRESENTING AND SEARCHING FOR AN OBJECT IN AN IMAGE

ASSISTANT COMMISSIONER FOR PATENTS
WASHINGTON, D.C. 20231

Sir:

Transmitted herewith is an amendment in the above-identified application.

☒ No additional fee is required.

☐ Small entity status of this application under 37 C.F.R. §1.9 and §1.27 has been established by a verified statement previously submitted.

☐ Small entity status of this application under 37 C.F.R. §1.9 and §1.27 has been established by a verified statement submitted herewith.

☒ Additional documents filed herewith: PCT Transmittal Letter/Notice of Priority/Drawings (2 Sheets)
English Translation of Specification/Request for Consideration/Declaration/PCT/IB/308/Assignments(2)
Form PTO-1595(2)/Preliminary Amendment/International Search Report/Check for $1,154.00

The fee has been calculated as shown below.

	(Col. 1)		(Col. 2)	(Col. 3)	SMALL ENTITY		OTHER THAN A SMALL ENTITY	
	CLAIMS REMAINING AFTER		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE	ADDITIONAL FEE	RATE	ADDITIONAL FEE
TOTAL	* 23	MINUS	** 23	= 0	X9 =	$	X18 =	$ .00
INDEP	* 5	MINUS	*** 5	= 0	X40 =	$	X80 =	$ .00
☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM					+135=	$	+270=	$
					TOTAL	$	TOTAL	$ .00

__ A check in the amount of $_____ is attached.

XX Please charge any additional fees for the papers being filed herewith and for which no check is enclosed herewith, or credit any overpayment to deposit Account No. 15-0030. A duplicate copy of this sheet is enclosed.

XX If these papers are not considered timely filed by the Patent and Trademark Office, then a petition is hereby made under 37 C.F.R. §1.136, and any additional fees required under 37 C.F.R. §1.136 for any necessary extension of time may be charged to deposit Account No. 15-0030. A duplicate copy of this sheet is enclosed.

22850

OBLON, SPIVAK, McCLELLAND,
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*If the entry in Column 2 is less than the entry in Column 1 write "0" in Column 3.
**If the "Highest Number Previously paid for" IN THIS SPACE is less than 20 write "20" in this space.
***If the "Highest Number Previously paid for" IN THIS SPACE is less than 3 write "3" in this space.7/93

204207US2PCT

IN THE UNITED STATES PATENT & TRADEMARK OFFICE

IN RE APPLICATION OF: :

MIROSLAW Z. BOBER : ATTN: APPLICATION DIVISION

SERIAL NO: NEW U.S. PCT APPL :
(Based on PCT/JP00/04673)

FILED: HEREWITH : EXAMINER:

FOR: METHOD, APPARATUS, COMPUTER: PROGRAM, COMPUTER SYSTEM AND COMPUTER-READABLE STORAGE FOR REPRESENTING AND SEARCHING FOR AN OBJECT IN AN IMAGE

PRELIMINARY AMENDMENT

ASSISTANT COMMISSIONER FOR PATENTS
WASHINGTON, D.C. 20231

SIR:

Prior to a first examination on the merits, please amend the above-identified application as follows:

IN THE CLAIMS

--4. (Amended) A method as claimed in claim 1 wherein an additional parameter corresponds to the eccentricity of the outline.

5. (Amended) A method as claimed in claim 1 wherein an additional parameter corresponds to the circularity of the outline.

6. (Amended) A method as claimed in claim 1 wherein at least one additional parameter uses a region-based representation.

8. (Amended) A method as claimed in claim 6 wherein an additional parameter is based on Fourier descriptors.

10. (Amended) A method of representing a plurality of objects appearing in a still or video image, by processing signals corresponding to the images, the method comprising, for each object outline, determining if there are significant changes in curvature in the object outline, and, if there are significant changes in curvature of the object outline, then deriving a shape descriptor using a method as claimed in claim 1 and, if there are no significant changes in curvature of the object outline, then deriving a shape descriptor including at least said additional parameter reflecting the shape of the object outline.

12. (Amended) A method of searching for an object in a still or video image by processing signals corresponding to images, the method comprising inputting a query in the form of a two-dimensional outline, deriving a descriptor of said outline using a method as claimed in claim 1, and comparing said query descriptor with each descriptor for stored objects using a matching procedure using the CSS values and the additional parameters to derive a similarity measure, and selecting and displaying at least one result corresponding to an image containing an object for which the comparison indicates a degree of similarity between the query and said object.

15. (Amended) A method as claimed in claim 13 where a=1 when there are no CSS peaks associated with either outline and a=0 when at least one outline has a CSS peak.

17. (Amended) An apparatus adapted to implement a method as claimed in claim 1.

18. (Amended) A computer program for implementing a method as claimed in claim 1.

19. (Amended) A computer system programmed to operate according to a method as claimed in claim 1.

20. (Amended) A computer-readable storage medium storing computer-executable process steps for implementing a method as claimed in claim 1.--

REMARKS

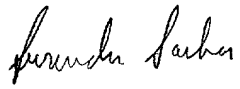
Favorable consideration of this application, as presently amended, is respectfully requested.

The present preliminary amendment is submitted to place the above-identified application in more proper format under United States practice. By the present preliminary amendment the claims have been amended to no longer recite any improper multiple dependencies.

The present application is believed to be in condition for a full and thorough examination on the merits. An early and favorable consideration of the present application is hereby respectfully requested.

Respectfully submitted,

OBLON, SPIVAK, McCLELLAND,
MAIER & NEUSTADT, P.C.



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Marked-Up Copy
Serial No:
_____
Amendment Filed on:
_____

IN THE CLAIMS

--4. (Amended) A method as claimed in [any one of claims 1 to 3] claim 1 wherein an additional parameter corresponds to the eccentricity of the outline.

5. (Amended) A method as claimed in [any one of claims 1 to 4] claim 1 wherein an additional parameter corresponds to the circularity of the outline.

6. (Amended) A method as claimed in [any one of claims 1 to 5] claim 1 wherein at least one additional parameter uses a region-based representation.

8. (Amended) A method as claimed in claim 6 [or claim 7] wherein an additional parameter is based on Fourier descriptors.

10. (Amended) A method of representing a plurality of objects appearing in a still or video image, by processing signals corresponding to the images, the method comprising, for each object outline, determining if there are significant changes in curvature in the object outline, and, if there are significant changes in curvature of the object outline, then deriving a shape descriptor using a method as claimed in [any one of claims 1 to 9] claim 1 and, if there are no significant changes in curvature of the object outline, then deriving a shape descriptor including at least said additional parameter reflecting the shape of the object outline.

12. (Amended) A method of searching for an object in a still or video image by processing signals corresponding to images, the method comprising inputting a query in the form of a two-dimensional outline, deriving a descriptor of said outline using a method as

claimed in [any one of claims 1 to 11] claim 1, and comparing said query descriptor with each descriptor for stored objects using a matching procedure using the CSS values and the additional parameters to derive a similarity measure, and selecting and displaying at least one result corresponding to an image containing an object for which the comparison indicates a degree of similarity between the query and said object.

15. (Amended) A method as claimed in claim 13 [or claim 14] where a=1 when there are no CSS peaks associated with either outline and a=0 when at least one outline has a CSS peak.

17. (Amended) An apparatus adapted to implement a method as claimed in [any one of claims 1 to 16] claim 1.

18. (Amended) A computer program for implementing a method as claimed in [any one of claims 1 to 16] claim 1.

19. (Amended) A computer system programmed to operate according to a method as claimed in [any one of claims 1 to 16] claim 1.

20. (Amended) A computer-readable storage medium storing computer-executable process steps for implementing a method as claimed in [any one of claims 1 to 16] claim 1.--

SPECIFICATION

Method, Apparatus, Computer program, Computer system and Computer-readable storage for Representing and Searching for an Object in an Image

Technical Field

The present invention relates to the representation of an object appearing in a still or video image, such as an image stored in a multimedia database, especially for searching purposes, and to a method and apparatus for searching for an object using such a representation.

Background Art

In applications such as image or video libraries, it is desirable to have an efficient representation and storage of the outline or shape of objects or parts of objects appearing in still or video images. A known technique for shape-based indexing and retrieval uses Curvature Scale Space (CSS) representation. Details of the CSS representation can be found in the papers "Robust and Efficient Shape Indexing through Curvature Scale Space" Proc. British Machine Vision conference, pp 53-62, Edinburgh, UK, 1996 and "Indexing an Image Database by Shape Content using

Curvature Scale Space" Proc. IEE Colloquium on Intelligent Databases, London 1996, both by F. Mokhtarian, S. Abbasi and J. Kittler, the contents of which are incorporated herein by reference.

The CSS representation uses a curvature function for the outline of the object, starting from an arbitrary point on the outline. The curvature function is studied as the outline shape is evolved by a series of deformations which smooth the shape. More specifically, the zero crossings of the derivative of the curvature function convolved with a family of Gaussian filters are computed. The zero crossings are plotted on a graph, known as the Curvature Scale Space, where the x-axis is the normalised arc-length of the curve and the y-axis is the evolution parameter, specifically, the parameter of the filter applied. The plots on the graph form loops characteristic of the outline. Each convex or concave part of the object outline corresponds to a loop in the CSS image. The co-ordinates of the peaks of the most prominent loops in the CSS image are used as a representation of the outline.

To search for objects in images stored in a database matching the shape of an input object, the CSS

representation of an input shape is calculated. The similarity between an input shape and stored shapes is determined by comparing the position and height of the peaks in the respective CSS images using a matching algorithm.

It is also known from the first-mentioned paper above to use two additional parameters, circularity and eccentricity of the original shape, to reject from the matching process shapes with significantly different circularity and eccentricity parameters.

A problem with the representation as described above is that retrieval accuracy is sometimes poor, especially for curves which have a small number of concavities or convexities. In particular, the representation cannot distinguish between various convex curves.

An aspect of the present invention is to introduce an additional means of describing the shape of the "prototype contour shape". The prototype contour shape is defined here preferably as:

1) The original shape if there are no convexities or concavities in the contour (i.e. there are no peaks in the CSS image), or

2) The contour of the shape after smoothing equivalent

to the highest peak in the CSS image.

Note, that the prototype contour shape is always convex.

For example, the shape of the prototype contour can be described by means of the invariants based on region moments as described in the paper "Visual Pattern Recognition by Moments Invariants", IEEE Transaction on Information Theory, Vol. IT-8, 179-187, 1962 by M.K. Hu the contents of which are incorporated herein by reference or using the Fourier descriptors as described in the paper "On Image Analysis by the Methods of Moments", IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 10, No. 4, July 1988, by Cho-Huak The, the contents of which are incorporated herein by reference, or parameters such as eccentricity, circularity, etc. In the known method mentioned above, eccentricity and circularity is only used in relation to the original shape. Here we use it in relation to a "prototype shape", which is different for curves which have at least one CSS peak. Another difference is that in the known method eccentricity and circularity are used to reject certain shapes from the similarity matching, and here we use them (in addition to CSS peaks) to derive the value of the similarity measure. Finally, we extend the additional

parameters used in the matching process to the moment invariants, Fourier descriptors and Zernike Moments.

As a result of the invention, the retrieval accuracy can be improved.

Disclosure of Invention

A method of representing an object appearing in a still or video image, by processing signals corresponding to the image set forth in claim 1, the method comprises deriving a curvature scale space (CSS) representation of the object outline by smoothing the object outline, deriving at least one additional parameter reflecting the shape or mass distribution of a smoothed version of the original curve, and associating the CSS representation and the additional parameter as a shape descriptor of the object.

In a method set forth in claim 2, an additional parameter relates to the smoothed outline corresponding to a peak in the CSS image.

In a method set forth in claim 3, an additional parameter relates to the smoothed outline corresponding to the highest peak in the CSS image.

In a method set forth in claim 4, an additional parameter corresponds to the eccentricity of the outline.

In a method set forth in claim 5, an additional parameter corresponds to the circularity of the outline.

In a method set forth in claim 6, at least one additional parameter uses a region-based representation.

In a method set forth in claim 7, an additional parameter is a region moment invariant.

In a method set forth in claim 8, an additional parameter is based on Fourier descriptors.

In a method set forth in claim 9, an additional parameter is based on Zernike moments of the region enclosed by the outline.

A method of representing a plurality of objects appearing in a still or video image, by processing signals corresponding to the images set forth in claim 10, the method comprises, for each object outline, determining if there are significant changes in curvature in the object outline, and, if there are significant changes in curvature of the object outline, then deriving a shape descriptor using a method as claimed in any one of claims 1 to 9 and, if there are no significant changes in curvature of the object outline, then deriving a shape descriptor including at least said additional parameter reflecting the shape of the object outline.

In a method set forth in claim 11, the additional parameter for an object outline having no significant changes in curvature is based on region moment invariants,

Fourier descriptors or Zernike moments of the outline.

A method of searching for an object in a still or video image by processing signals corresponding to images set forth in claim 12, the method comprises inputting a query in the form of a two-dimensional outline, deriving a descriptor of said outline using a method as claimed in any one of claims 1 to 11, and comparing said query descriptor with each descriptor for stored objects using a matching procedure using the CSS values and the additional parameters to derive a similarity measure, and selecting and displaying at least one result corresponding to an image containing an object for which the comparison indicates a degree of similarity between the query and said object.

In A method set forth in claim 13, the similarity measure is based on M where M = a*GP-S+CSS-S where GP-S is the similarity measure between additional parameters of the compared object outlines and CSS-S is the similarity measure between the CSS values for the compared object outlines, and a is a constant.

In a method set forth in claim 14, a depends on the number and height of the CSS peaks.

In a method set forth in claim 15, a=1 when there are

no CSS peaks associated with either outline and a=0 when at least one outline has a CSS peak.

A method of searching for an object in a still or video image by processing signals corresponding to images set forth in claim 16, the method comprisies calculating a similarity measure between two object outlines using a CSS representation of said outlines and additional parameters reflecting the shape of or mass distribution within the original outline or a smoothed version of the outline.

An apparatus set forth in claim 17 is adapted to implement a method as claimed in any one of claims 1 to 16.

A computer program set forth in claim 18 implements a method as claimed in any one of claims 1 to 16.

A computer system set forth in claim 19 is programmed to operate according to a method as claimed in any one of claims 1 to 16.

A computer-readable storage medium set forth in claim 20 stores computer-executable process steps for implementing a method as claimed in any one of claims 1 to 16.

A method of representing objects in still or video images set forth in claim 21 is described with reference to the accompanying drawings.

A method of searching for objects in still or video images set forth in claim 22 is described with reference to the accompanying drawings.

A computer system set forth in claim 23 is described with reference to the accompanying drawings.

Brief Description of the Drawings

Fig. 1 is a block diagram of a video database system;

Fig. 2 is a drawing of an outline of an object; and

Fig. 3 is a CSS representation of the outline of Fig. 2.

Best Mode for Carrying Out the Invention

First embodiment

Fig. 1 shows a computerised video database system according to an embodiment of the invention. The system includes a control unit 2 in the form of a computer, a display unit 4 in the form of a monitor, a pointing device 6 in the form of a mouse, an image database 8 including stored still and video images and a descriptor database 10 storing descriptors of objects or parts of objects appearing in images stored in the image database 8.

A descriptor for the shape of each object of interest appearing in an image in the image database is derived by the control unit 2 and stored in the descriptor database 10. The control unit 2 derives the descriptors operating under the control of a suitable program implementing a method as described below.

Firstly, for a given object outline, a CSS representation of the outline is derived. This is done using the known method as described in one of the papers mentioned above.

More specifically, the outline is expressed by a representation $\Psi = \{(x(u), y(u), u \in [0, 1]\}$ where u is a normalised arc length parameter.

The outline is smoothed by convolving Ψ with an ID Gaussian kernel g(u, σ), and the curvature zero crossings of the evolving curve are examined as σ changes. The zero crossing are identified using the following expression for the curvature:

$$k(u,\sigma) = \frac{X_u(u,\sigma)Y_{uu}(u,\sigma) - X_{uu}(u,\sigma)Y_u(u,\sigma)}{(X_u(u,\sigma)^2 + Y_u(u,\sigma)^2)^{3/2}}$$

where

$$X(u,\sigma) = x(u) * g(u,\sigma) \qquad Y(u,\sigma) = y(u) * g(u,\sigma)$$

and

$$X_u(u,\sigma) = x(u) * g_u(u,\sigma) \qquad X_{uu}(u,\sigma) = x(u) * g_{uu}(u,\sigma)$$

In the above, * represents convolution and subscripts represent derivatives.

The number of curvature zero crossings changes as σ changes, and when σ is sufficiently high Ψ is a convex curve with no zero crossings.

The zero crossing points (u, σ) are plotted on a graph, known as the CSS image space. This results in a plurality of curves characteristic of the original outline. The peaks of the characteristic curves are identified and the corresponding co-ordinates are extracted and stored. In general terms, this gives a set of n co-ordinate pairs

[(x1,y1), (x2,y2), ... (xn,yn)], where n is the number of peaks, and xi is the arc-length position of the ith peak and yi is the peak height. These peak co-ordinates constitute the CSS representation.

In addition to the CSS representation, further parameters are associated with the shape to produce the shape descriptor. In this embodiment, the additional parameters are the eccentricity and circularity of the "prototype region" for the shape, where the "prototype region" of the shape is the contour of the shape after the final smoothing step, that is, at the point equivalent to the highest peak value σ. Other values of σ can be selected for the prototype region. This results in a shape descriptor for a shape S in the form: {EPR, CPR, PEAKS} where EPR represents the eccentricity of the prototype region, CPR the circularity of the prototype region, and PEAKS the CSS representation.

A method of searching for an object in an image in accordance with an embodiment of the invention will now be described.

Here, the descriptor database 10 of the system of Fig. 1 stores shape descriptors derived according to the method

described above.

The user initiates a search by drawing an object outline on the display using the pointing device. The control unit 2 then derives a shape descriptor of the input outline in the manner described above. The control unit then performs a matching comparison with each shape descriptor stored in the database.

Suppose the input outline, Shape S1, is being compared with a stored shape S2, S1 and S2 being respective descriptors:

S1: {EPR1, CPR1, PEAKS1}

S2: {EPR2, CPR2, PEAKS2}

Where EPR means Eccentricity of the prototype region and CPR means Circularity of the prototype region, and PEAKS means the set of coordinates of peaks in the CSS image (the set can be empty). The similarity measure between two shapes is computed as follows.

M = *a**abs((EPR2-EPR1)/(EPR2+EPR1)) + *b**abs((CPR2-CPR1)/ ((CPR2+CPR1))+SM(PEAKS1, PEAKS2)

Where *a* and *b* are two coefficients and SM is the standard similarity measure defined on the two sets of peaks [1], and *abs* denotes absolute value. SM is calculated using

a known matching algorithm such as described in the above-mentioned papers can be used. That matching procedure is briefly described below.

Given two closed contour shapes, the image curve Ψi and the model curve Ψm and their respective sets of peaks {(xi1,yi1),(xi2,yi2),...,(xin,yin)} and {(xm1,ym1), (xm2,ym2), ... , (xmn,ymn)} the similarity measure is calculated. The similarity measure is defined as a total cost of matching of peaks in the model into peaks in the image. The matching which minimises the total cost is determined using a dynamic programming. The algorithm recursively matches the peaks from the model to the peaks from the image and calculates the cost of each such match. Each model peak can be matched with only one image peak and each image peak can be matched with only one model peak. Some of the model and or image peak may remain unmatched, and there is an additional penalty cost for each unmatched peak. Two peaks can be matched if their horizontal distance is less than 0.2. The cost of a match is the length of the straight line between the two matched peaks. The cost of an unmatched peak is its height.

In more detail the algorithm works by creating and

expanding a tree-like structure, where nodes correspond to matched peaks:

1. Create starting node consisting of the largest maximum of the image (xik,yik) and the largest maximum of the model (xir,yir).

2. For each remaining model peak which is within 80 percent of the largest maximum of the image peaks create an additional starting node.

3. Initialise the cost of each starting node created in 1 and 2 to the absolute difference of the y-coordinate of the image and model peaks linked by this node.

4. For each starting node in 3, compute the CSS shift parameter alpha, defined as the difference in the x (horizontal) coordinates of the model and image peaks matched in this starting node. The shift parameter will be different for each node.

5. For each starting node, create a list of model peaks and a list of image peaks. The list hold information which peaks are yet to be matched. For each starting node mark peaks matched in this node as "matched", and all other peaks as "unmatched".

6. Recursively expand a lowest cost node (starting

from each node created in steps 1-6 and following with its children nodes) until the condition in point 8 is fulfilled. To expand a node use the following procedure:

7. Expanding a node:

If there is at least one image and one model peak left unmatched:

select the largest scale image curve CSS maximum which is not matched (xip,yip). Apply the starting node shift parameter (computed in step 4) to map the selected maximum to the model CSS image - now the selected peak has coordinates (xip-alpha, yip). Locate the nearest model curve peak which is unmatched (xms,yms). If the horizontal distance between the two peaks is less than 0.2 (i.e: |xip-alpha- xms | < 0.2), match the two peaks and define the cost of the match as the length of the straight line between the two peaks. Add the cost of the match to the total cost of that node. Remove the matched peaks from the respective lists by marking them as "matched". If the horizontal distance between the two peaks is greater than 0.2, the image peak (xip,yip) cannot be matched. In that case add its height yip to the total cost and remove only the peak (xip,yip) from the image peak list by marking it as

"matched".

Otherwise (There are only image peaks or there are only model peaks left unmatched):

Define the cost of the match as the height of the highest unmatched image or model peak and remove that peak from the list.

8. If after expanding a node in 7 there are no unmatched peaks in both the image and model lists, the matching procedure is terminated. The cost of this node is the similarity measure between the image and model curve. Otherwise, go to point 7 and expand the lowest cost node.

The above procedure is repeated with the image curve peaks and the model curve peaks swapped. The final matching value is the lower of the two.

The above steps are repeated for each model in the database.

The similarity measures resulting from the matching comparisons are ordered and the objects corresponding to the descriptors having similarity measures indicating the closest match (i.e. here the lowest similarity measures) are then displayed on the display unit 4 for the user. The number of objects to be displayed can be pre-set or selected

by the user.

In an alternative implementation, different parameters can be used to describe the shape of the "prototype region". For example three Fourier coefficients of the curve can be used. The similarity measure can be defined as follows:

$$M = a*EUC(F1,F2) + SM(PEAKS1,PEAKS2)$$

Where EUC is a Euclidean distance between vectors F1 and F2 formed from three main Fourier Coefficients of the model and image shape, a is a constant, and SM represents the similarity measure for the CSS peaks, calculated using a method essentially as described above.

Industrial Applicability

A system according to the invention may, for example, be provided in an image library. Alternatively, the databases may be sited remote from the control unit of the system, connected to the control unit by a temporary link such as a telephone line or by a network such as the internet. The image and descriptor databases may be provided, for example, in permanent storage or on portable data storage media such as CD-ROMs or DVDs.

Components of the system as described may be provided in software or hardware form. Although the invention has been described in the form of a computer system, it could be implemented in other forms, for example using a dedicated chip.

Specific examples have been given of methods of representing a 2D shape of an object and of methods for calculating values representing similarities between two shapes but any suitable such methods can be used.

The invention can also be used, for example, for matching images of objects for verification purposes, or for filtering.

CLAIMS

1. A method of representing an object appearing in a still or video image, by processing signals corresponding to the image, the method comprising deriving a curvature scale space (CSS) representation of the object outline by smoothing the object outline, deriving at least one additional parameter reflecting the shape or mass distribution of a smoothed version of the original curve, and associating the CSS representation and the additional parameter as a shape descriptor of the object.

2. A method as claimed in claim 1 wherein an additional parameter relates to the smoothed outline corresponding to a peak in the CSS image.

3. A method as claimed in claim 2 wherein an additional parameter relates to the smoothed outline corresponding to the highest peak in the CSS image.

4. A method as claimed in any one of claims 1 to 3 wherein an additional parameter corresponds to the eccentricity of the outline.

5. A method as claimed in any one of claims 1 to 4 wherein an additional parameter corresponds to the circularity of the outline.

6. A method as claimed in any one of claims 1 to 5 wherein at least one additional parameter uses a region-based representation.

7. A method as claimed in claim 6 wherein an additional parameter is a region moment invariant.

8. A method as claimed in claim 6 or claim 7 wherein an additional parameter is based on Fourier descriptors.

9. A method as claimed in claim 6 wherein an additional parameter is based on Zernike moments of the region enclosed by the outline.

10. A method of representing a plurality of objects appearing in a still or video image, by processing signals corresponding to the images, the method comprising, for each object outline, determining if there are significant changes

in curvature in the object outline, and, if there are significant changes in curvature of the object outline, then deriving a shape descriptor using a method as claimed in any one of claims 1 to 9 and, if there are no significant changes in curvature of the object outline, then deriving a shape descriptor including at least said additional parameter reflecting the shape of the object outline.

11. A method as claimed in claim 10 wherein the additional parameter for an object outline having no significant changes in curvature is based on region moment invariants, Fourier descriptors or Zernike moments of the outline.

12. A method of searching for an object in a still or video image by processing signals corresponding to images, the method comprising inputting a query in the form of a two-dimensional outline, deriving a descriptor of said outline using a method as claimed in any one of claims 1 to 11, and comparing said query descriptor with each descriptor for stored objects using a matching procedure using the CSS values and the additional parameters to derive a similarity

measure, and selecting and displaying at least one result corresponding to an image containing an object for which the comparison indicates a degree of similarity between the query and said object.

13. A method as claimed in claim 12 wherein the similarity measure is based on M where M = a*GP-S+CSS-S where GP-S is the similarity measure between additional parameters of the compared object outlines and CSS-S is the similarity measure between the CSS values for the compared object outlines, and a is a constant.

14. A method as claimed in claim 13 where a depends on the number and height of the CSS peaks.

15. A method as claimed in claim 13 or claim 14 where a=1 when there are no CSS peaks associated with either outline and a=0 when at least one outline has a CSS peak.

16. A method of searching for an object in a still or video image by processing signals corresponding to images, the method comprising calculating a similarity measure

between two object outlines using a CSS representation of said outlines and additional parameters reflecting the shape of or mass distribution within the original outline or a smoothed version of the outline.

17. An apparatus adapted to implement a method as claimed in any one of claims 1 to 16.

18. A computer program for implementing a method as claimed in any one of claims 1 to 16.

19. A computer system programmed to operate according to a method as claimed in any one of claims 1 to 16.

20. A computer-readable storage medium storing computer-executable process steps for implementing a method as claimed in any one of claims 1 to 16.

21. A method of representing objects in still or video images substantially as hereinbefore described with reference to the accompanying drawings.

22. A method of searching for objects in still or video images substantially as hereinbefore described with reference to the accompanying drawings.

23. A computer system substantially as hereinbefore described with reference to the accompanying drawings.

ABSTRACT

A method of representing an object appearing in a still or video image, by processing signals corresponding to the image, comprises deriving a curvature scale space (CSS) representation of the object outline by smoothing the object outline, deriving at least one additional parameter reflecting the shape or mass distribution of a smoothed version of the original curve, and associating the CSS representation and the additional parameter as a shape descriptor of the object.

FIG. 1

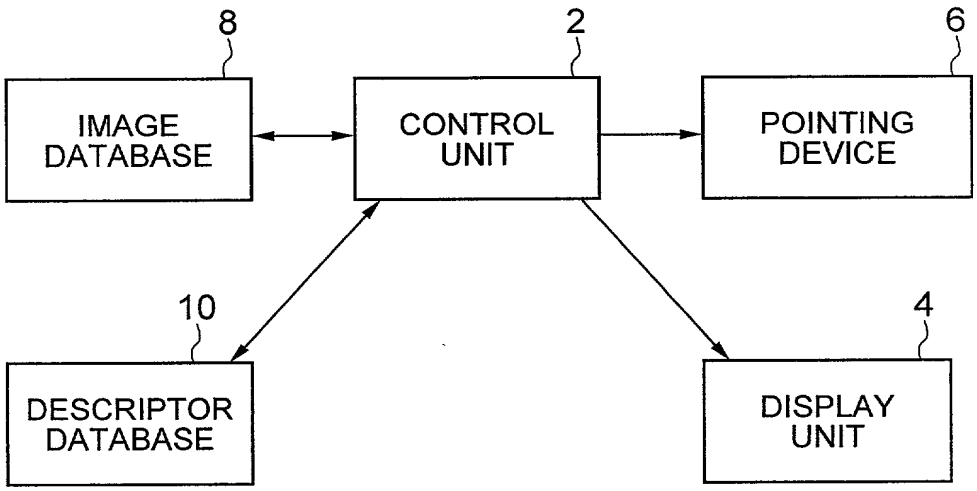


FIG. 2

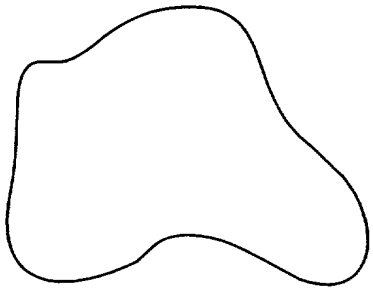
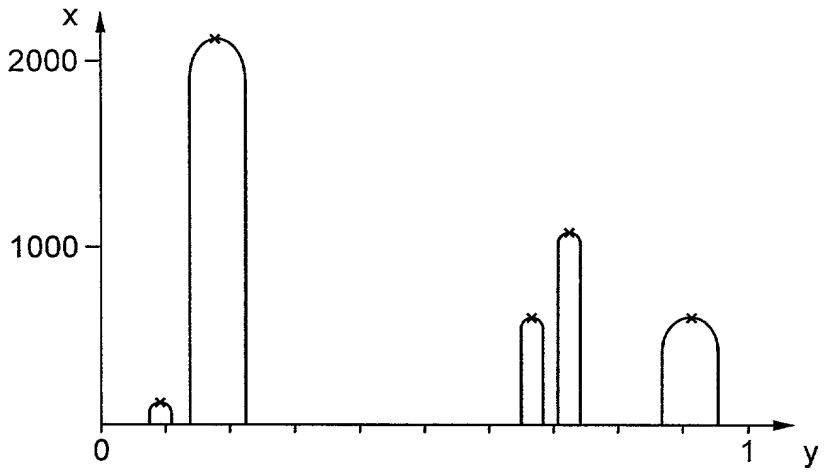


FIG. 3



Declaration and Power of Attorney For Patent Application

特許出願宣言書及び委任状

Japanese Language Declaration

日本語宣言書

下記の氏名の発明者として、私は以下の通り宣言します。

As a below named inventor, I hereby declare that:

私の住所、私書箱、国籍は下記の私の氏名の後に記載された通りです。

My residence, post office address and citizenship are as stated next to my name.

下記の名称の発明に関して請求範囲に記載され、特許出願している発明内容について、私が最初かつ唯一の発明者（下記の氏名が一つの場合）もしくは最初かつ共同発明者（下記の名称が複数の場合）であると信じています。

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled.

METHOD, APPARATUS, COMPUTER PROGRAM, COMPUTER SYSTEM AND COMPUTER-READABEL STORAGE FOR REPRESENTING AND SEARCHING FOR AN OBFECT IN AN IMAGE

上記発明の明細書は、

the specification of which

☐ 本書に添付されています。

☐ is attached hereto.

☐ ___月___日に提出され、米国出願番号または特許協定条約国際出願番号を_____とし、

☒ was filed on July 12, 2000 as United States Application Number or PCT International Application Number PCT/JP00/04673 and was amended on _____ (if applicable).

☐ （該当する場合）_____に訂正されました。

私は、特許請求範囲を含む上記訂正後の明細書を検討し、内容を理解していることをここに表明します。

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

私は、連邦規則法典第37編第1条56項に定義されるとおり、特許資格の有無について重要な情報を開示する義務があることを認めます。

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

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私は、米国法典第35編119条（a）-（d）項又は365条（b）項に基づき下記の、米国以外の国の少なくとも一ヵ国を指定している特許協力条約365（a）項に基づく国際出願、又は外国での特許出願もしくは発明者証の出願についての外国優先権をここに主張するとともに、優先権を主張している、本出願の前に出願された特許または発明者証の外国出願を以下に、枠内をマークすることで、示しています。

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Prior Foreign Application(s)
外国での先行出願

(Number) (番号)	(Country) (国名)	(Day/Month/Year Filed) (出願年月日)	Priority Claimed 優先権主張 Yes はい	No いいえ
9916684.5	U.K.	15 / 07 / 1999	☒	☐
			☐	☐

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(Application No.) (出願番号)	(Filing Date) (出願日)

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(Application No.) (出願番号)	(Filing Date) (出願日)	(Status: Patented, Pending, Abandoned) (現況：特許許可済、係属中、放棄済)

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委任状：私は下記の発明者として、本出願に関する一切の手続きを米特許商標局に対して遂行する弁理士または代理人として、下記の者を指名いたします。
(弁護士、または代理人の指名及び登録番号を明記のこと)

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国籍	Citizenship
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(Supply similar information and signature for third and subsequent joint inventors.)